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Analysis of existing onshore Hydrocarbon Pipeline for Conversion to Dense Phase CO2 service

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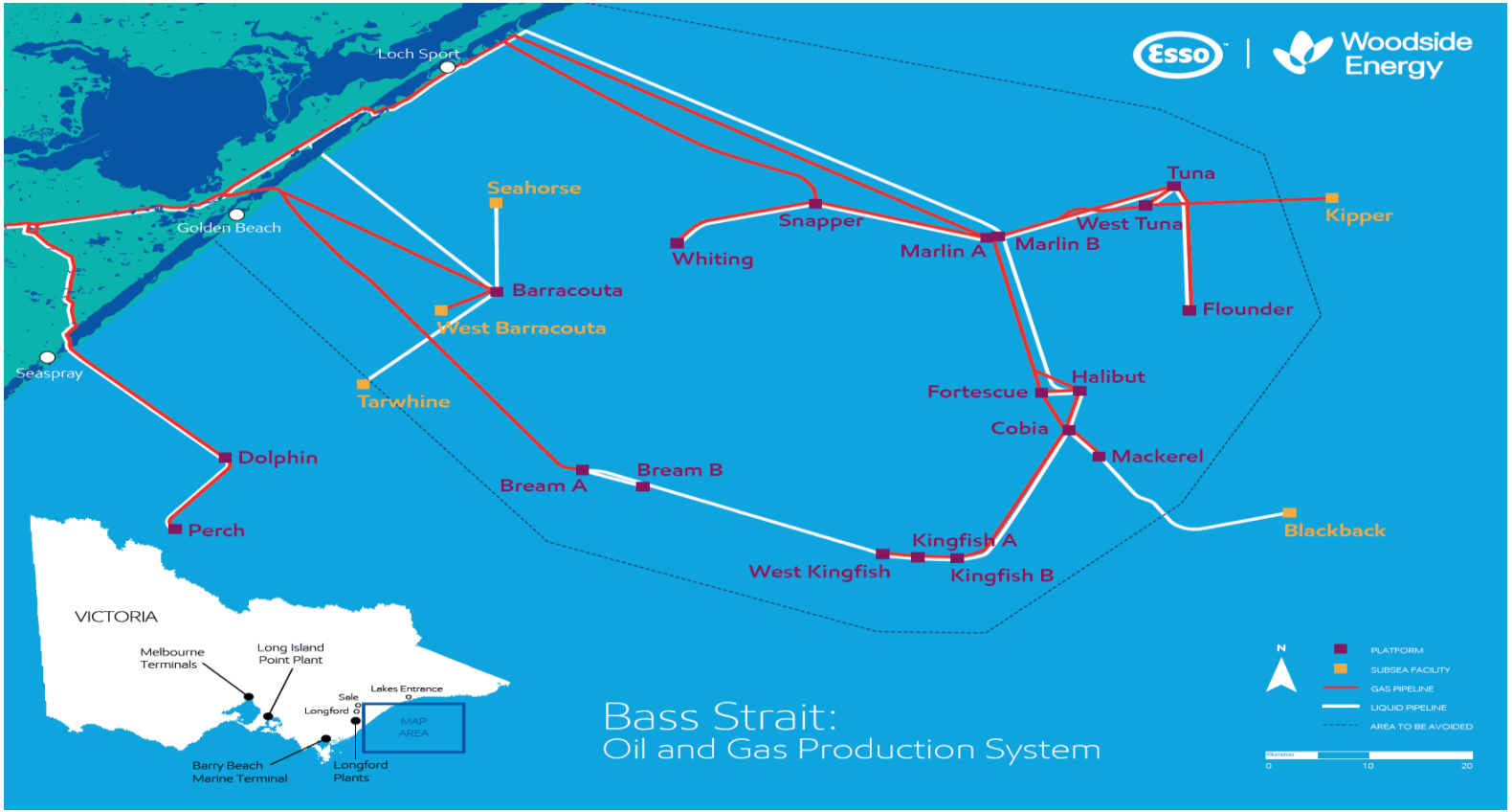
Bass Strait History



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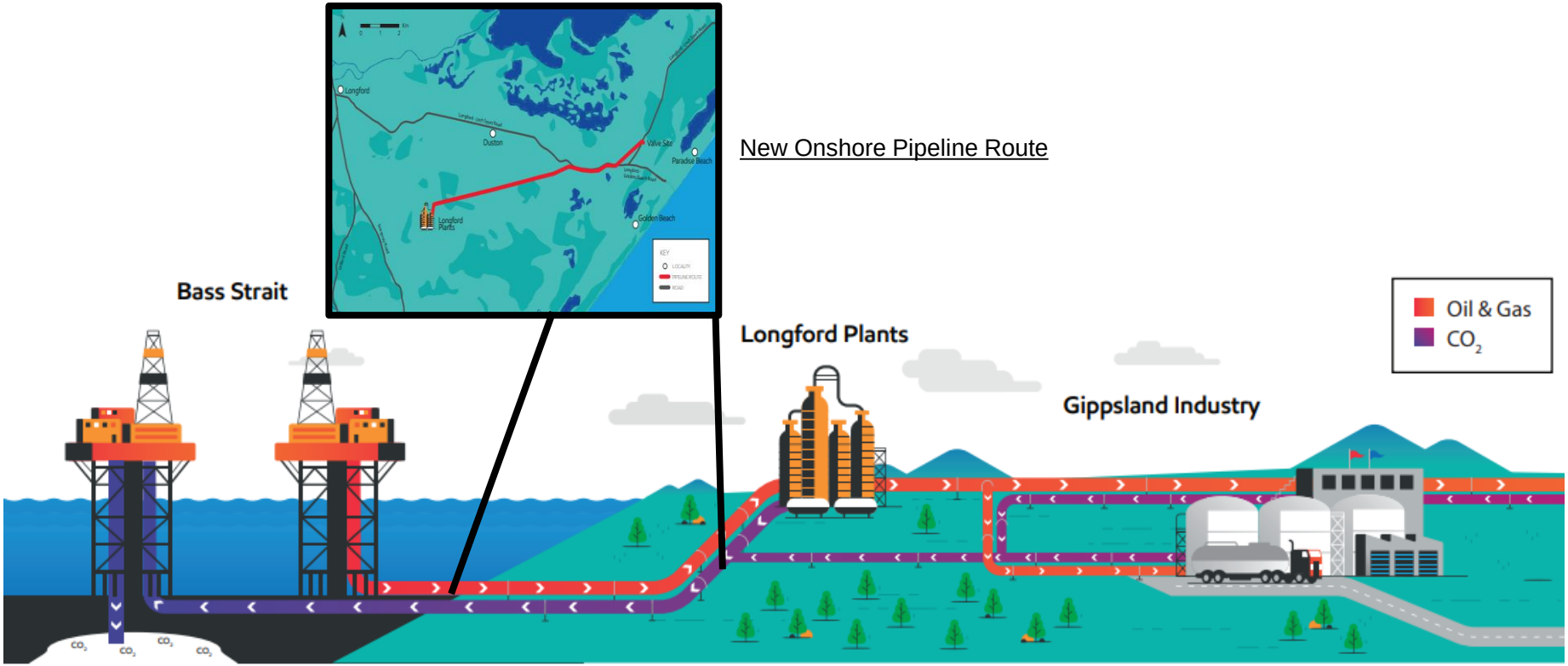
Plan for Carbon Capture – South East Australia CCS

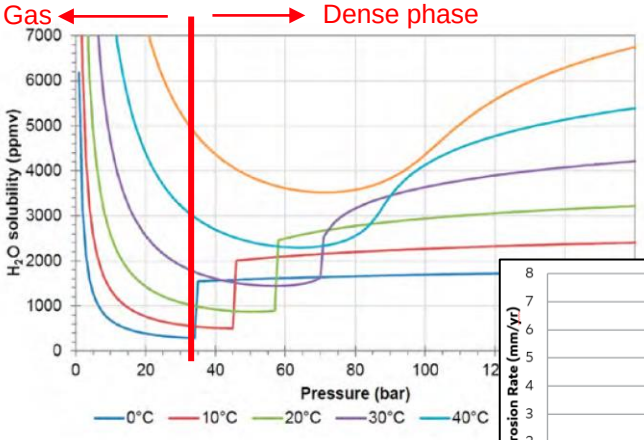


New Onshore Pipeline Route

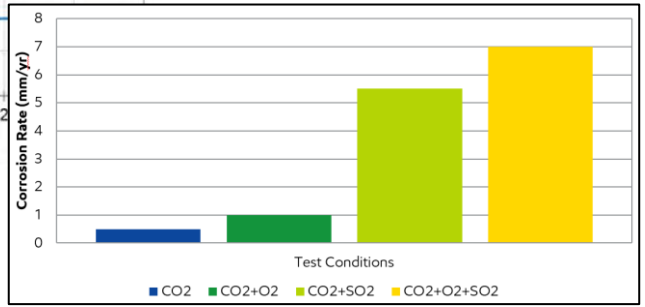
SEA CCS Overview

Internal Corrosion Challenge

ACID FORMATION

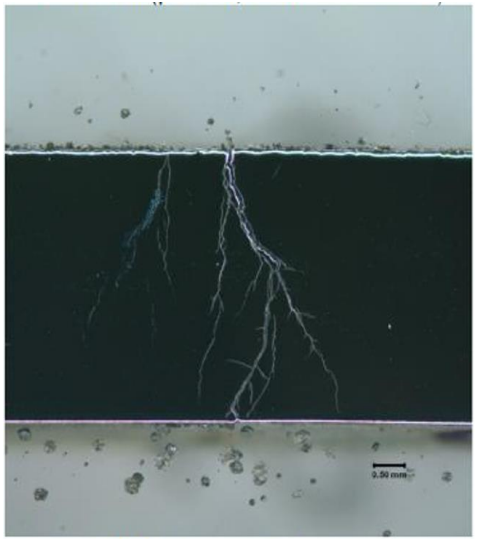


Water Solubility in CO2



Corrosion rates of trace elements

STRESS CORROSION CRACKING



CO Stress Corrosion Cracking (x20 Mag)

* Choi, Nesic & Young (2010)

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Internal Corrosion Control

Corrosion Control **Initial recommendations** based on corrosion testing and literature review

Contaminant	Specification Value	Motivation for limitation
H_2O for pipeline	100 - 300 ppm 50 ppm if NOx/SOx >10 ppm	Pipeline corrosion
H_2O for LCO_2 shipping	50 ppm	Hydrate formation
CO	1000 ppm	Stress corrosion cracking (SCC) and personnel exposure limits
H_2S	100 ppm 10 ppm if NOx/SOx >10 ppm	Sour service cracking
NOx	<10 ppm	Potential formation of strong acid HNO3
SOx	<10 ppm	Potential formation of strong acid H2SO4
H_2	0.5%, 1%*	Embrittlement, *for new built, sour service, X65 grade or lower
O_2	80 ppm	Pitting/crevice corrosion of 25Cr in well tubular
Volatiles (e.g., N2, Ar, C1)	<4.5% for pipeline <0.5% for LCO_2 shipping	Economic considerations: compression power, pipeline capacity Shipping: ability to liquify stream
Glycol	TBD	Corrosion, potential concern for TEG dehydration

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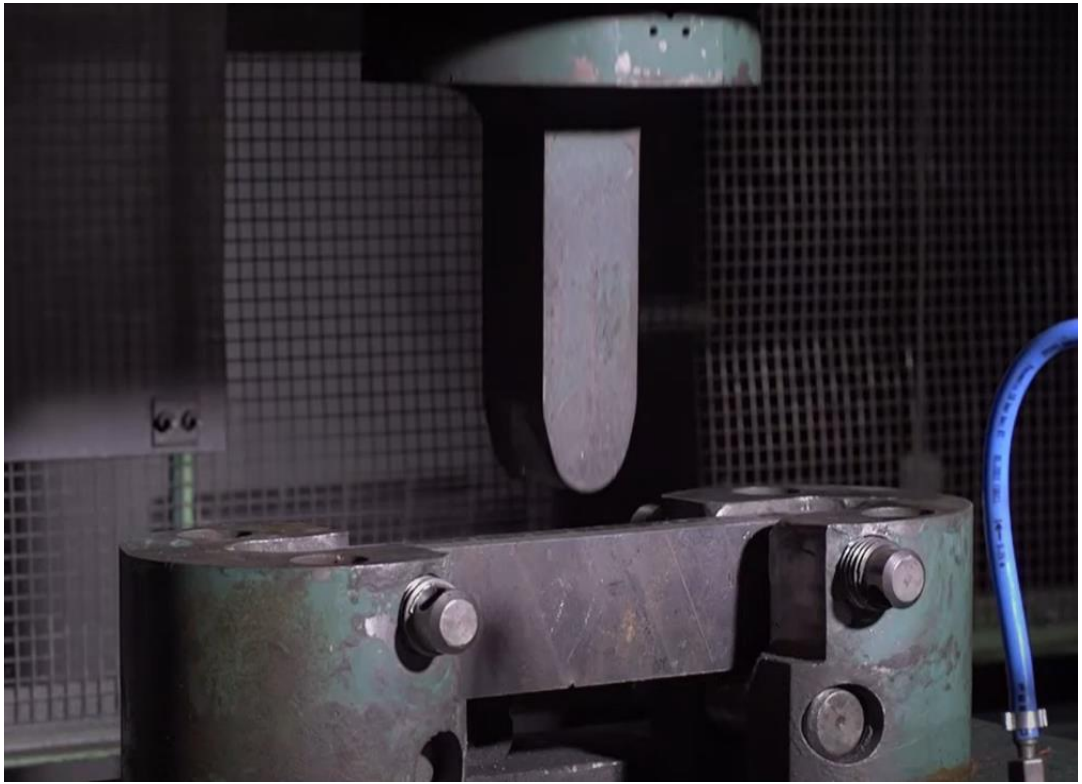
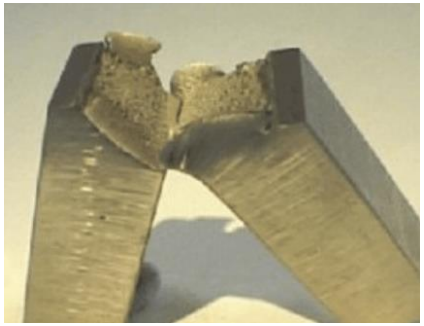
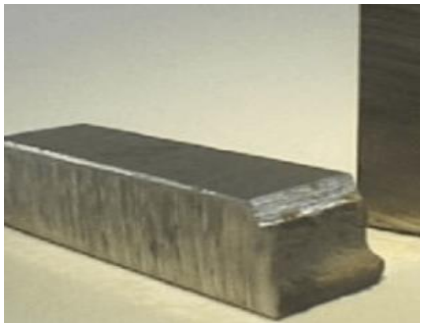
Brittle Fracture Challenge





Ductile Failure



Brittle Failure

Source: www.bf-labor.de (Youtube); UMIST.ac.uk

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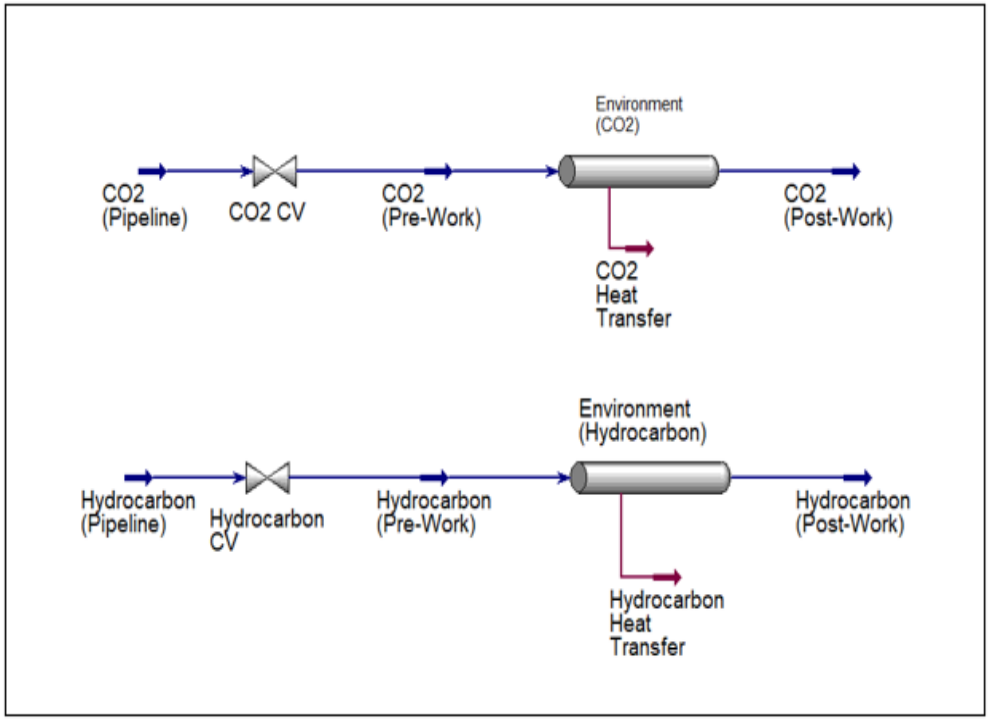
Brittle Fracture Comparison – CO2 versus Hydrocarbon



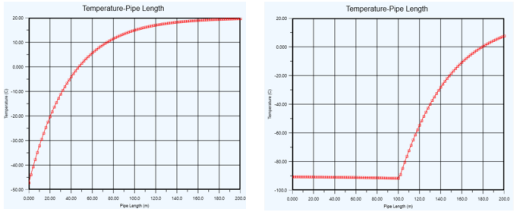
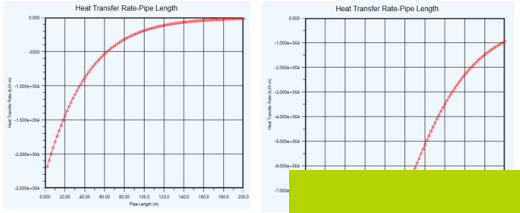


Figure 8: Temperature Profile for environmental Exposure of Hydrocarbon gas (L) versus Dense Phase CO2 (R)

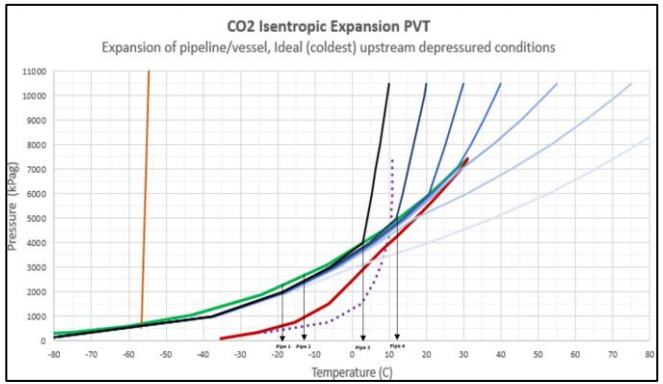


CO2

Hydrocarbon (Methane)

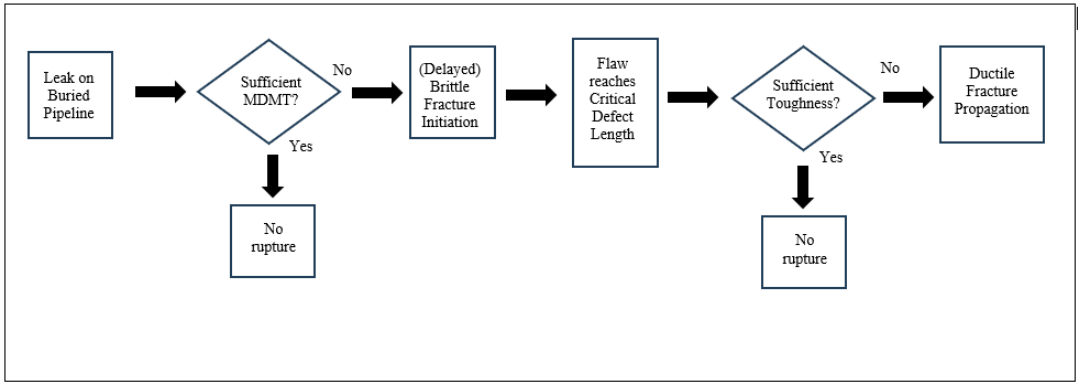
Cooling Capacity Comparison

Brittle Fracture Control



85 Mpa Hoop stress Criterion

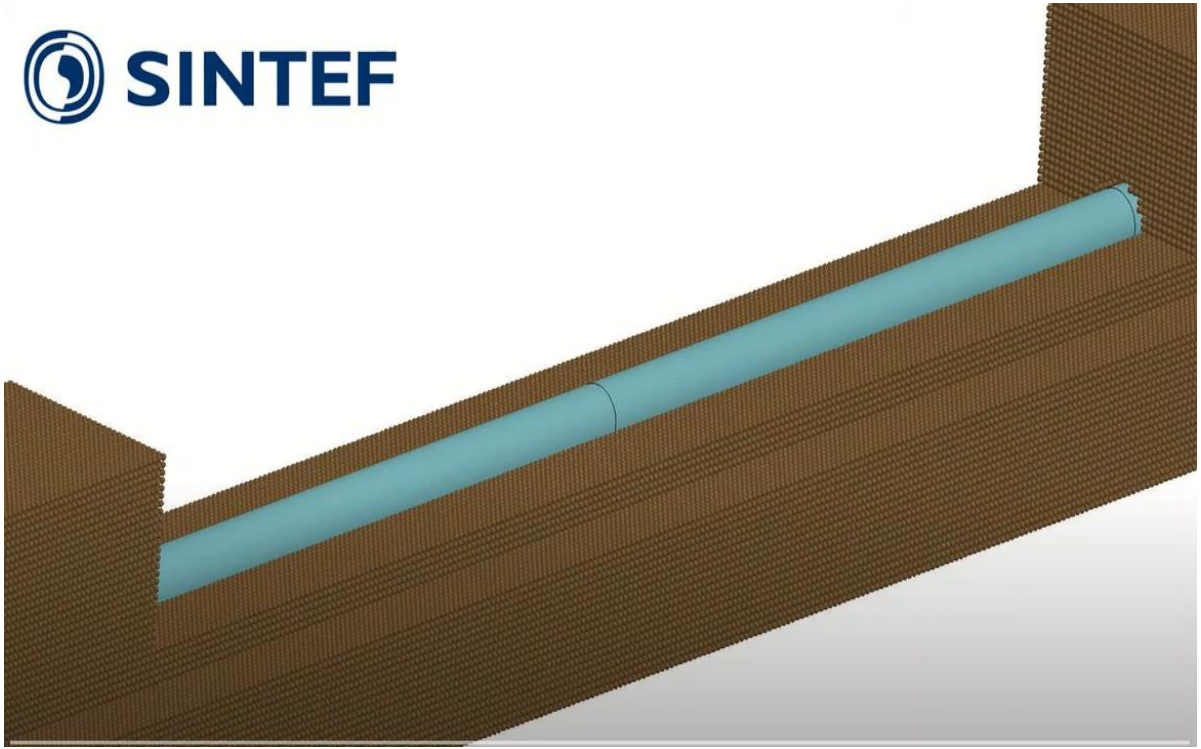
- Determine associated pressure
- Calculate associated temperature
- Compare with Minimum Design Material Temperature (MDMT)



Conservative basis suggests use of **MDMT of -40°C** will provide adequate low temperature toughness

- Aligns with latest advice from NACE Guide 21532-2023

Ductile Fracture Challenge

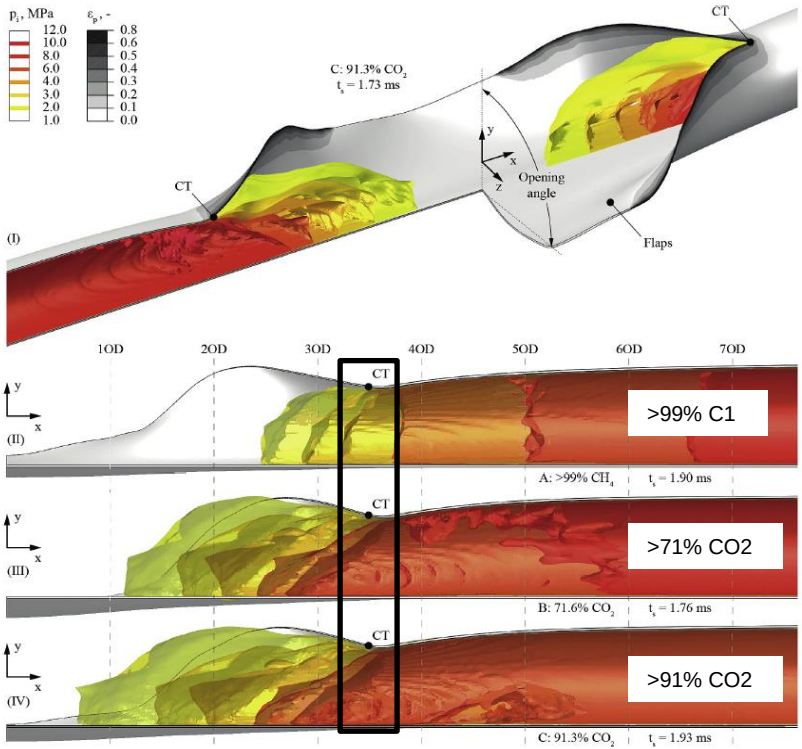


Simulation of Ductile (Running Fracture)

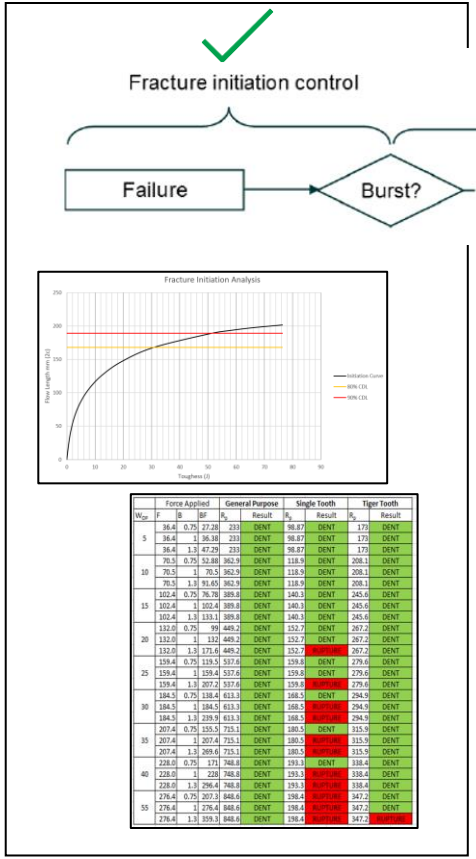
Carmichael Mississippi Pipeline Rupture

Source: Sintef (Youtube); NTSB Report PAR-09/01

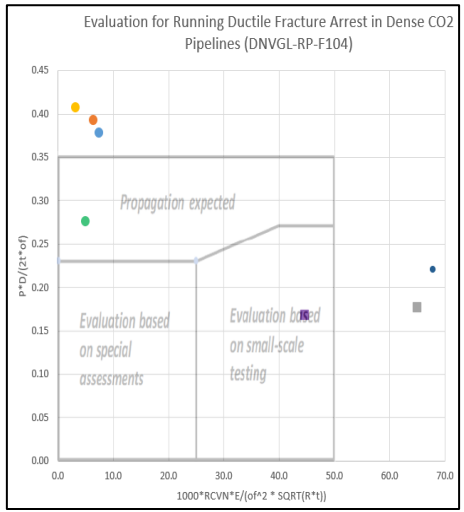
Ductile Fracture Control



* Keim, et al (2019)



	Force Applied			General Purpose		Single Tooth		Tiger Tooth	
W_{CVF}	F	B	BF	R_b	Result	R_b	Result	R_b	Result
5	36.4	0.75	27.28	233	DENT	98.87	DENT	173	DENT
	36.4	1	36.38	233	DENT	98.87	DENT	173	DENT
	36.4	1.3	47.29	233	DENT	98.87	DENT	173	DENT
10	70.5	0.75	52.88	362.9	DENT	118.9	DENT	208.1	DENT
	70.5	1	70.5	362.9	DENT	118.9	DENT	208.1	DENT
	70.5	1.3	91.65	362.9	DENT	118.9	DENT	208.1	DENT
15	102.4	0.75	76.78	389.8	DENT	140.3	DENT	245.6	DENT
	102.4	1	102.4	389.8	DENT	140.3	DENT	245.6	DENT
	102.4	1.3	133.1	389.8	DENT	140.3	DENT	245.6	DENT
20	132.0	0.75	99	449.2	DENT	152.7	DENT	267.2	DENT
	132.0	1	132	449.2	DENT	152.7	DENT	267.2	DENT
	132.0	1.3	171.6	449.2	DENT	152.7	RUPTURE	267.2	DENT
25	159.4	0.75	119.5	537.6	DENT	159.8	DENT	279.6	DENT
	159.4	1	159.4	537.6	DENT	159.8	DENT	279.6	DENT
	159.4	1.3	207.2	537.6	DENT	159.8	RUPTURE	279.6	DENT
30	184.5	0.75	138.4	613.3	DENT	168.5	DENT	294.9	DENT
	184.5	1	184.5	613.3	DENT	168.5	RUPTURE	294.9	DENT
	184.5	1.3	239.9	613.3	DENT	168.5	RUPTURE	294.9	DENT
35	207.4	0.75	155.5	715.1	DENT	180.5	DENT	315.9	DENT
	207.4	1	207.4	715.1	DENT	180.5	RUPTURE	315.9	DENT
	207.4	1.3	269.6	715.1	DENT	180.5	RUPTURE	315.9	DENT
40	228.0	0.75	171	748.8	DENT	193.3	DENT	338.4	DENT
	228.0	1	228	748.8	DENT	193.3	RUPTURE	338.4	DENT
	228.0	1.3	296.4	748.8	DENT	193.3	RUPTURE	338.4	DENT
55	276.4	0.75	207.3	848.6	DENT	198.4	RUPTURE	347.2	DENT
	276.4	1	276.4	848.6	DENT	198.4	RUPTURE	347.2	DENT
	276.4	1.3	359.3	848.6	DENT	198.4	RUPTURE	347.2	RUPTURE



Ultimately, the project aims to potentially reduce large scale emissions in line with ExxonMobil`s and Australia`s carbon emission reduction goals

Thank you

References

- Choi, Nesic and Young (2010) “Effect of Impurities on the Corrosion Behaviour of CO2 Transmission Pipeline Steel in Supercritical CO2-water Environments”. Environmental Science & Technology Vol 44.

- DNV (2021) “Design and Operation of Carbon Dioxide Pipelines”. DNVGL-RP-F104:2021 (DNV)

- Keim, et al (2019), “Fluid-structure-interaction modeling of dynamic fracture propagation in pipelines transporting natural gases and CO2-mixtures”. International Journal of Pressure Vessels and Piping

- Mahgerefteh, Zhang & Brown (2014) “Modelling Brittle Fracture Propagation in Gas and Dense-phase CO2 Transportation Pipelines”. University College London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